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OPTIMIZATION OF EXTRUSION BLOW MOULDING PROCESS USING PARISON PROGRAMMING TECHNIQUE

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ABSTRACT

Nowadays, polymeric materials play the significant roles in the consumer world due to its low density and higher strength to weight ratio. In the present work, High Density Polyethylene bottle made of extrusion blow moulding is analyzed using finite element analysis. The control of blow moulded parts' thickness distribution is essential in ensuring product quality, better mechanical performance, lower manufacturing cost and raw material usage. In this process, the final part thickness depends on the raw material called parison thickness distribution. So, it is required to optimize the blow moulding process by considering its parameters such as mould closing velocity, melt temperature and blow pressure to achieve uniform final part thickness. The parison thickness distributions are predicted using FEA software and optimized using parison programming technique.

KEYWORDS: Extrusion Blow Moulding Process, HDPE, Parison Thickness & Process Simulation

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Original Article

1. INTRODUCTION

There is a major raise in the use of polymer products in beverages, cosmetics, chemical products, pharmaceuticals industries. In particular, products made of extrusion blow moulding process are in more demand in fulfilling the needs of the society. The various applications of this process are packaging industries, automobile, office and pharmaceutical sectors, etc. The three main phases of blow moulding process are formation of preform, inflation of preform around the mould, and cooling of part and its solidification. The thickness distribution of final part depends on the parison thickness distributions. In industry, the thickness distribution of final part is often achieved by trial and error method. However, it is a tedious work and purely depends on the operators' skills. Moreover, the manufacturing cost of such part is also very high. Due to such complexities, the modern industry cannot lie on the trial and error method.

There is a predominant growth in the use of computer-aided tools such as CAE techniques in analyzing the blow mould design. One such CAE tool is ANSYS Polyflow. It is used for simulating and analyzing the CFD problems such as extrusion blow moulding process. In this process, maintaining the constant wall thickness of final product turns out to be a tedious task as the structure of the product becomes more complex. In this case, the constant wall thickness distribution can be achieved by controlling the thickness distribution of its preform known as parison. But getting it naturally becomes a challenging one. So, it is suitable to take computer aided tools such as Polyflow.

The computer aided tool, Polyflow can facilitate the simulation of blow moulding process and selection of optimal parison thickness in order to obtain the uniform final product thickness. The designed geometry features

such as parison thickness also affect the material usage in this process. In the present work, the objective is to simulate the blow moulding process to analysis the variation in thickness of the part and to optimize it.

2. LITERATURE REVIEW

The optimization of parison thickness was conducted by several authors to find the effect of change in thickness on the final wall thickness of the component. The following reviews on literature showed the importance of optimization of parison thickness in achieving better component wall thickness. Geng et al.,(2007) developed a hybrid method using FEM, soft computing techniques to optimize the parison thickness for a blow moulded part with required thickness distribution. Szczepanski et al., (2006) investigated the occurrence of uncertainty in the blow moulding process which influences the shape, size and quality of the products. Hsu et al., (2004) optimized the optimal die gap openings and die geometry in the blow moulding process using fuzzy logic. Thaboub et al., (2004) applied the design of experiments for optimizing the extrusion blow moulding process. Gauvin et al., (2003) applied the gradient-based numerical optimization to find the optimal parameters for a blow moulding process.

Yu et al., (2002) applied the process optimization to get the uniform thickness in the blown parts, design optimization to obtain minimum part weight subjected to stress constraints. Haung et al., (2003) analyzed the blend composition and flow rate of parison by considering the influence of its swell and sag diameter. Huang et al., (2002) found that the neural network had good predictive ability in determining the parison thickness in blow moulding process. Laroche et al., (1999) developed an optimal search method using finite element method and a gradient technique in determining the optimal distribution of parison thickness. Lee & Soh (1996) optimized the preform wall thickness to achieve better wall thickness of blow moulded part using FEA technique. This model was also experimentally validated. Dutta & Ryan (1982) employed a pinch-off mould technique and experimental photography in studying the blow moulding process. Rosato et al., (2004) provided an insight into the critical areas of product design, quality, zero defects and cost. In this work, they fully explained the standards of blow moulding process, which could help both the commercial and academic people to gain in depth knowledge.

3. SIMULATION METHODOLOGY

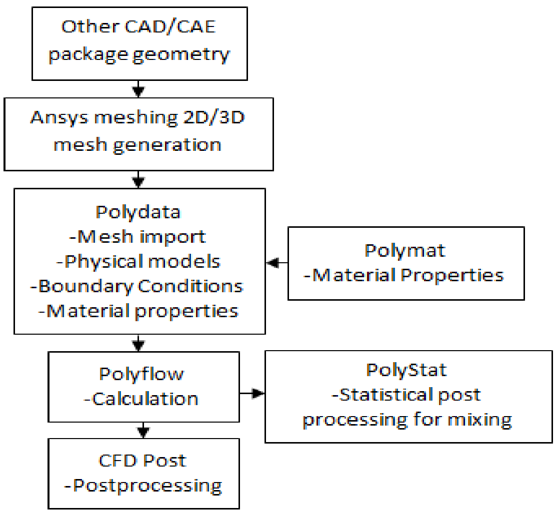

Figure 1: Flow Chart.

4. FEA SIMULATION

In this work, a typical soap bottle with a handle was considered for FEA simulation. The uniform parison thickness distribution of extrusion moulding process was assumed. Further the parison pinch-off due to mould closing and inflation was evaluated. Both parison and mould were modeled with shell elements using CAD package, PROE wildfire 4. The geometric features of initial parison were as follows: 0.35 m height, 0.09m diameter and 0.002 m initial thickness. As the parison and mould were symmetrical, only half of them were required for simulation with a plane of symmetry containing the parison axis. It not only reduced the computational time, but also gave the accurate results. The mesh file had both mould and parison model meshed using Ansys ICEM CFD. It comprised of 1136 Quadrilateral elements and 1213 nodes. With the availability of mesh file, all the details regarding contact condition, boundary condition and flow conditions were given as data file. The two sub domains of the data file were parison and mould. Parison was subdomain1 (SD1) and mould was subdomain2 (SD2). SD1 identified the fluid parison, on which material data, inflation pressure and contact were defined. Boundary conditions for symmetricity were selected along the four sides of the domain defining the fluid parison.

A Type of flow model: Shell Model. Generalized Newtonian non- isothermal.

B Flow Boundary Condition

BS1 identified the upper border, the plane of symmetry was oriented along the z-direction.

BS2 identified one vertical border, the plane of symmetry was oriented along the x-direction.

BS3 identified the lower border, the plane of symmetry was oriented along the z-direction.

BS4 identified the other vertical border, the plane of symmetry was oriented along the x direction.

C Fluid parison contact with mould

The contact of fluid parison with mould was achieved by mould movement and fluid inflation progressively using blowing pressure. It eventually acquired the mould shape.

D Membrane Element

The membrane element was assumed because the fluid parison's thickness was much lower than its height and diameter. Further, the thickness/diameter aspect ratio certainly allowed usage of membrane element to suit for 3-D blow moulding analysis.

E Lagrangian Representation

A Lagrangian representation was spontaneously selected with respect to the membrane element. In this representation, the mesh nodes were treated as material points. Additionally, nodal displacement was achieved by integrating time of nodal velocity.

F Material Properties

Parison material was considered as High-Density Polyethylene (HDPE).

Density: 960 kg/m^3

Viscosity: 92140 Pa.s

Die Temperature: 185° C

Inertia terms were taken into account

An initial thickness of 3 mm was specified on the layer.

For mould material atmospheric temperature was maintained.

G Operating Condition

SD1 identified the fluid parison, on which material data, inflation pressure and contact were defined. An evolution scheme was selected for the inflation pressure. A pre-blowing pressure was also applied. When using the membrane element, inflation or shaping pressure received a sign in accordance with the element orientation. The set inflation pressure was 10^5 Pa.

SD2 identified the mould; the fluid parison would enter into contact with the mould in order to shape the bottle. The process involved parison pinch-off: in other words, both mould parts move at an assigned speed until closing. The set mould closing speed was -0.5 m/s.

5. EVOLUTION SCHEME

The present case involved a mould motion followed by the inflation. In addition, a moderate pre-blowing pressure was applied during the pinch-off process, and this in order to get enough material for shaping the handle.

For the mould motion, the x-velocity component was imposed:

V_x = -50 cm/s.

It depended on time t by means of a ramp function f(t), with (a, b) = (0.097, 1) and (c, d) = (0.103, 0). Figure 2 presents the parameters a, b, c, d of the ramp function. A short interval was selected for stopping the mould motion. This ramp function f(t) had been selected in such a way that the mould would end its motion at the plane of symmetry cutting the parison.

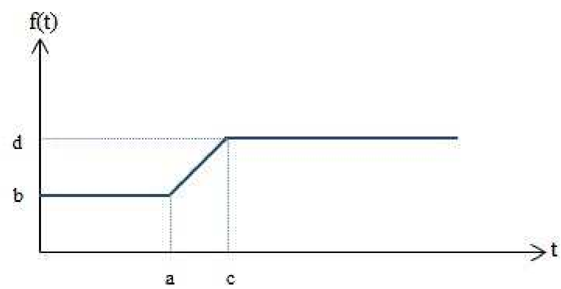

Figure 2: Ramp Function.

A time-dependent pressure was applied, the nominal value of which was 10^5 pa. It depended on time t by means of a ramp function f(t), with (a, b) = (0.1, 0.05) and (c, d) = (0.2, 1).

In particular, a pre-blowing pressure of 5 % was applied.

H Contact Condition

As seen, BS1 was the membrane which described the fluid parison. It was the computational domain for the fluid, some process parameters of blow moulding were inflation pressure and contact with a (moving) mould. Further the contact of mould with the fluid parison was a significant phenomenon in getting the desired shape.

Contact wall: Mould:

Penalty coefficient: 10^9 Pas/mm

Slipping coefficient: 10^9Pas/mm

Penetration accuracy: 0.1

Element dilatation: 0.5

I Numerical Parameters

To run the simulation in the post processing, it was required give the time step value and the maximum number of runs.

initial time: 0.0s

final time: 1.0s

tolerance: 0.01

max number of successful steps: 200

6. SIMULATION AND ANALYSIS

The graphical post processing was carried out using Ansys CFD Post.

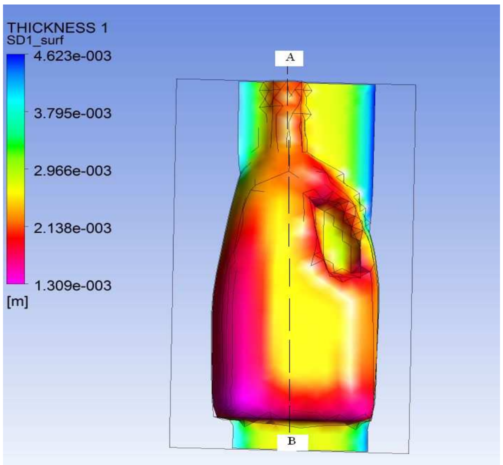

Figure 3: Result Shows the Thickness Distribution of the Bottle After Blowing.

The thickness distribution showed the occurrence of some non-uniformity, especially along edges. Also, the handle was rather thick. This originated from the combination of parison pinch-off and a moderate inflation.

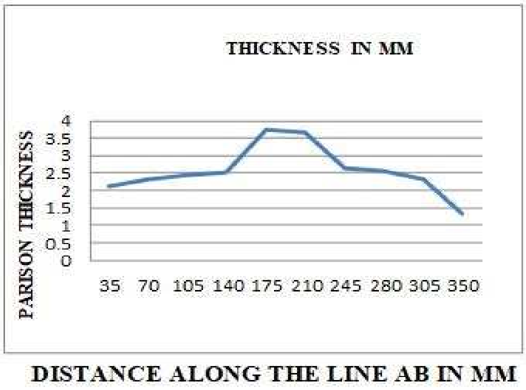

Figure 4: Graph Showing the Thickness Variation of Parison along its Length.

From the above figure it was observed that the thickness of the final product was not uniform throughout its length. So this could be achieved by optimization of parison thickness using parison programming.

7. PARISON PROGRAMMING

Step 1: The initial thickness of 3mm was given and run the simulation. At the end of it, the postprocessor was activated, and a file was generated containing a new initial thickness distribution.

Step 2: Then, a new simulation was run with this new initial thickness distribution.

Step 3: The Procedure was iterative. So, this procedure was repeated for 5 to 10 optimization steps until the solution was converged.

Step 4: The final thickness obtained was very close to the requested profile and with a minimum of mass.

After Optimization

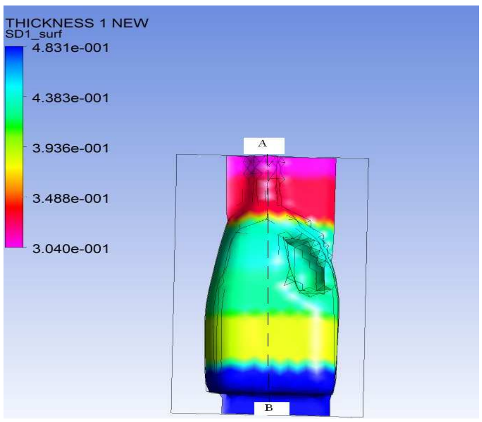

Figure 5: Result Shows the Thickness Distribution of the Bottle after Optimization.

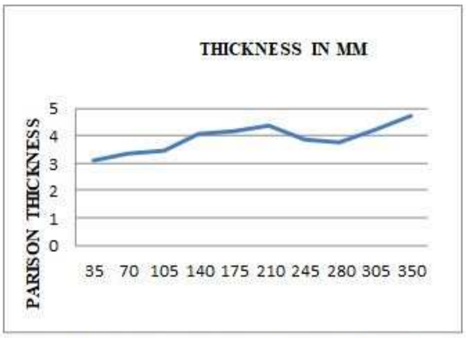

Figure 6: Graph Showing Thickness Variation after Optimization.

From this simulation of parison programming the thickness variation could be reduced to the minimum, i.e. before optimization the thickness variation along the length of parison was 2.4 mm and after optimization the thickness variation was 1.63mm. It showed the variation of thickness due to optimization and the thickness reached above the initial thickness, so it gave the required strength to the component.

8. CONCLUSIONS

The thickness distribution was not uniform throughout the bottle, it was required to optimize it. Parison Programming was a technique used here to optimize the thickness. By optimizing, the thickness variation could be reduced up to 33.33%. However, there was some deviation in thickness distribution, and it was due to the variation in mould design, variation in setting of parameters and swelling of parison due to variation in temperature difference.

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